Knowledge Transformation, Learning And Changes Giving Competitive Advantage In Aerospace Supply Chains

Abstract

The paper investigates three levels of learning – adaptive, reactive and expansive - for the transformation of knowledge to enhance innovation and competitive advantage in commercial aerospace supply chains. A perspective of supply chains as complex Activity Networks is used for data analysis based on in-depth interviews in a global setting. Themes for the interviews were identified through rigorous literature research. The paper provides evidence of levels of learning in commercial aerospace supply chains. We found that a) adaptive learning brings a supply chain up to present industrial standards only, b) reactive learning makes the supply chain competitive, and c) expansive learning gives the supply chain potential for competitive advantage. By considering supply chains as the interaction of different work activities, the forces of change can be better understood. The findings may be useful to practitioners in understanding the importance of different levels of learning to supply chain sustainability.

Keywords: Learning and knowledge, innovation, aerospace supply chains, activity networks, evolutionary complex systems.

1. Introduction

This paper identifies three levels of learning – adaptive, reactive and expansive – for the transformation of knowledge and the effects of learning for producing innovation and gaining competitive advantage.

Traditionally the large commercial aircraft manufacturer would define and specify exactly what their first tier suppliers should produce for them. This practice of high level of buyer dominance over suppliers has gradually changed, resulting in a worldwide reorganisation of the industry. This is characterised by the commercial airframe manufacturers giving their 1st tier of selected suppliers directly below them, responsibility for complete systems (Giunta et al, 2000).

Day and Atkinson (2004), argue that high impact suppliers have to commit themselves to cost reductions for long term business relationships, and create a culture of continuous improvement. However, to gain competitive advantage, more proactive responses are required. Nollet et al (2005) argue that this is achieved through producing innovative solutions in terms of technology and products.

Recent developments in supply chain strategies are therefore based on a focus upon the sharing of skills and capabilities (Cousins and Spekman, 2003). In the context of creating technologically more advanced products, supply chains need to become learning communities with skills in creating and transforming knowledge (Preiss and Murray, 2005). In that sense, Easterby-Smith et al (2005) highlight the absorptive capacity of a firm to appreciate and process external knowledge and the learning from past experiences. Engeström (1987), however, is more concerned about the learning and development experienced when moving away from the old. And this is about the creation of the new, i.e. innovation.

Risk-sharing partnerships combine these views in practice by bringing together the best expertise available to produce totally new concepts of aircraft design. These partnerships are the response to the need for sharing of skills, expertise and capabilities. This is driven by the fact that an airframe manufacturer cannot carry such huge investments in capital and expertise alone. The tight integration of risk-sharing partnerships can facilitate a totally new aircraft concept (Rose-Anderssen et al, 2008).

This paper therefore focuses on the levels of learning and knowledge transformation involved in the development of these practices.

An activity theoretical approach, viewing individual firms as work activities, and supply chains as complex networks of work activities is applied for analysing the processes of learning and change. Activity Theory, which is an early form of evolutionary complex systems thinking, was formed by L. Vygotsky, A.N. Leont'ev and A.R. Luria in Soviet-Russia in the 1920-30s. The theory is a philosophical framework for studying different forms of human practices and their intercation. Complex Systems Thinking, however, was developed by many authors including I. Prigogine and his colleagues in Brussels and Austin, H. Haken and his colleagues in Stutgart during the 1970s, and later at the Santa Fe Institute in the US.

This paper is interested in the impact of levels of learning on supply chain change to gain competitive advantage. To further this end, the perspective of supply chains as networks of work activities is introduced first along with a model of knowledge transformation, learning and the creation of radical solutions. Following justification of the methodology, case data are discussed in terms of the model, leading to conclusions regarding the level of learning for transformation of knowledge to enhance innovation and competitive advantage in commercial aerospace supply chains.

2. Complex activity networks, learning and development

Johnson and Ford (2005) have written about the dynamic practices of supply chain network interventions and its effect on new product development. Their suggested intervention is to develop strategic alliances for sharing competencies and capital investments. In that sense, networks of work activities are collective attempts to share competences and develop a common future.

A work activity is defined in Activity Theory as a developmental process connecting the individual and social levels through the human artefacts and the object orientation of the process. Work activities are characterised by the multi-voiced interaction created within them, and their potential for expansive transformation (Engeström, 2001). In these activities, there are continuous processes for creation of new instruments for change (Engeström, 1987).

The elements of the activity (figure 1) are represented by the individual subjects of consideration, their activity community, the object and the human artefacts. There are three mediating artefacts. The instruments mediate between the individual and the object. The social rules mediate between the individual and the activity community. And the division of labour mediates between the community and the object.

Individuals have goals for their actions, whilst the object gives a collective purpose and direction to an activity (Hasu and Engeström, 1999). The object in this sense can be seen as the visual target or focus collectively being communicated and created by the community of a particular activity. It is important to make clear that an object is not the same as objectives, which are rigidly independent of individual conceptions, personal bias, thoughts and feelings. An object on the other hand is the vision that integrates the elements of the activity. Because of its imprecise nature the object needs to be reproduced more and more accurately in knowledge by the activity community for individuals to comprehend (Lektorsky, 1977). Essential to the development of the activity is the individuals' orientation towards the object.

The instruments are the concepts, language, technologies and strategies the individuals use to influence the object (Vygotsky, 1978). In that sense language is an

essential instrument individuals are using to coordinate their actions with others (Blackler, 1993).

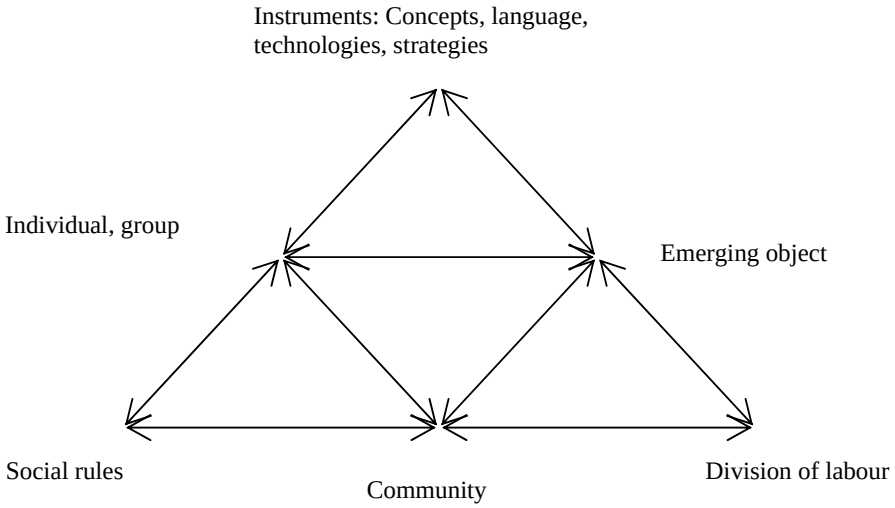

Figure 1 Complex activity network (Engeström, 1987)

Evolutionary complex systems are governed partly by the invisible effects resulting from the interaction of individuals possessing a diversity of opinions and experiences within a system (Rose-Anderssen and Allen, 2008). Work activities are therefore difficult to observe and comprehend. Due to the diverse opinions and experiences people in a complex human system have, the system as a whole may potentially respond to challenges from the environment in multiple and unpredictable ways (Allen, 2001). In practice, this means that sufficiently complex activities will have a diversity of potential behaviours within them. This gives them the capacity to go beyond the marginal improvements characterised by routine behaviour of a smooth and optimised terrain. That is, a complex work activity consists of a community of individuals with diverse perceptions, experiences and expertise. As such the community can explore more radically in a multidimensional “rough” performance landscape (Fig. 2), and as a result produce radical solutions (Rose-Anderssen et al, 2005). These are creative steps that are not foreseeable. Moving by only marginal changes in established routines, however, means that the community is merely ‘hill-climbing’ the smoother part of the terrain. This is just a rational extension of the present and will give marginal improvements only.

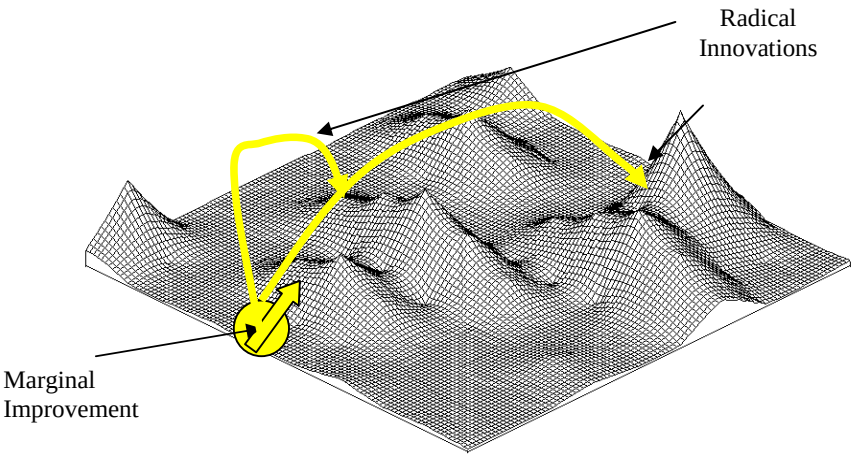

Figure 2 Multidimensional Performance Landscape

In this model of knowledge transformation and learning, there are three distinct and qualitatively different levels of learning in an activity (see figure 3). Adaptive learning takes place when people adapt to practices developed by others. Adaptive learning is therefore about an awareness that things can be done differently and that these alternatives may serve in adapting to a changing environment. It means that there may be an opportunity to adapt to practices of more successful competitors or industries. Reactive learning occurs when using routine practices in solving problems. Reactive learning is therefore about taking corrective action to perceived mistakes and learning from that. These two levels of learning do not challenge the practices of the past. Neither of these two forms of learning requires the development of unknown approaches as they are still applied in the smoother and more familiar part of the multidimensional performance landscape. Supply chains operating according to these approaches are using single voiced interactions of established routines and practices.

A third form of learning takes place as an expansion of the given context (Engeström, 1987). This form of learning may occur at boundaries where people meet and interact to form new meanings that go beyond the limits of the individual person alone. This is the learning that takes place due to multi-voiced interaction between the individuals within the work activity. In that context they challenge the practices and perceptions of the past by moving into the rough terrain of the unknown. At a supply chain level, the multi-voiced interaction is extended to the boundaries between the firms.

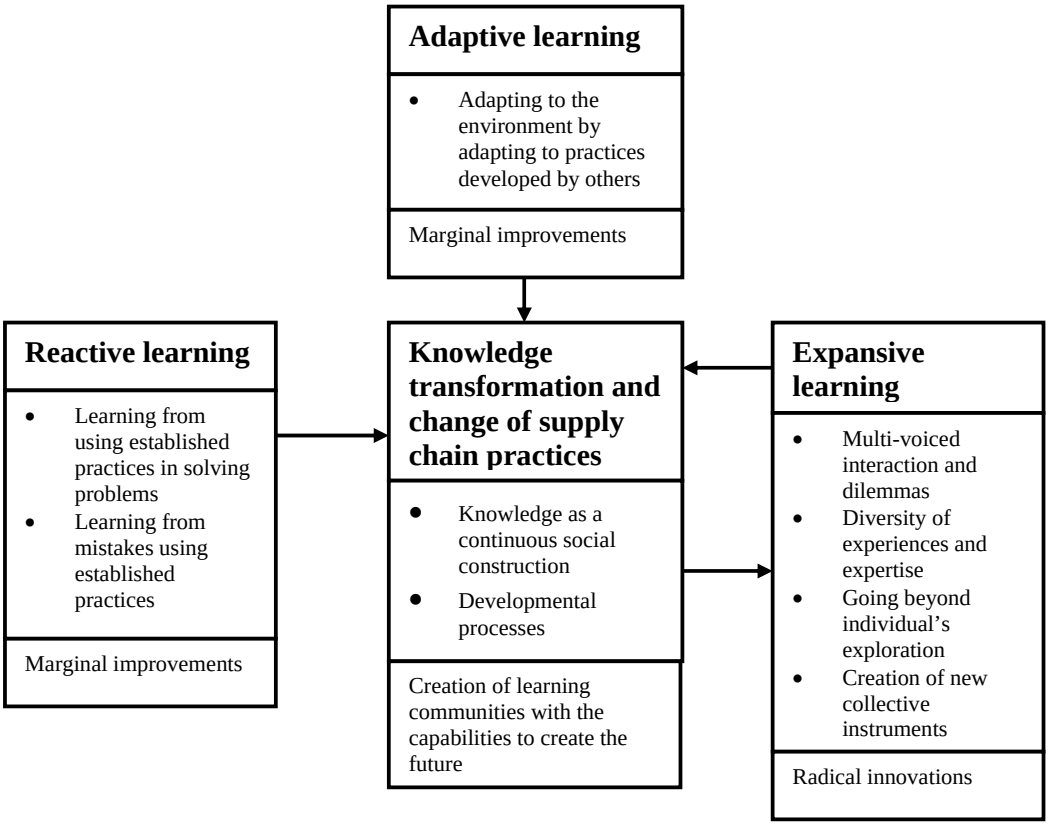

Figure 3 Knowledge transformation and learning

2.1 Learning and knowledge transformation

Traditionally wisdom has been seen as something people possess in their head. In this perspective, learning is therefore associated with the acquisition of data accumulated by others (Gherardi, 2006). From this position, wisdom is a commodity that can be easily transmitted and controlled. And knowledge is about what an organization has accumulated over time. However, a more post-modern and complex systems position is taken where knowledge or knowing is seen as a dynamic process that is mediated, situated, provisional, pragmatic and contested (Blackler, 1995). From this position, knowledge is a continuous social construction in the collective infrastructure of knowing how and what to learn for change. The social construction of knowledge through learning has the potential of moving the activity beyond the rational and marginal extension of the present and into the rougher terrain of exploration and innovation. The static form of monumental knowledge transfer is replaced by a process of knowledge transformation. In this context the learning within a supply chain would move away from a risk-aversive position towards a risk-sharing one, and be searching opportunities for creating a new future.

Vygotsky's (1934, 1978) principles of proximal development is based on the difference in problem solving done by a child acting alone and what can be achieved with the guidance of an adult. In terms of work activities this means bringing together people of different experiences, expertise and responsibilities to solve a challenge of

mutual interest (Rose-Anderssen and Allen, 2008). Through comparison and reflection these people are therefore being prepared to learn more and expand on what each of them could have achieved alone. This would mean going beyond each of the learner's previously acquired socially existing or documented forms of knowledge (Engeström, 1987). In the context of aerospace supply chains the success of the routines of the past are thereby challenged in order to produce more radical solutions in terms of practices, technologies and products.

2.2 Levels of learning; from adaptation to creation of the 'new'

In work activities there is a move from individual action to the object of collective activity. In developing the object, the distinctive feature of human activity is the continuous creation of new instruments (Engeström, 1987). Instruments are here seen as the tools individuals are using at a non-conscious level in performing routine tasks and as models of thought when solving problem tasks.

Although the collective behaviour of a work activity in principle should be characterised by a continuous process of change, the dynamics of change might be inhibited by the success of past practices, technologies and products. Following a success, for example, there is a tendency to simply use established routines again. The collective object that should be driving and guiding eventual changes to the activity has therefore been frozen. Thus new instruments that could transform the object are not created. Radical change of a work activity may therefore not be a natural choice of strategy for a single firm or from a supply chain management point of view. In such cases it might be more natural to keep to adaptive and reactive forms of learning.

To change from the successful routines of the past means a change of mind-sets. This might rely on significant disturbances within the market environment and therefore a need for change. In that case, the alternative to adaptive and reactive forms of learning is expansion which transcends the old context. The potential of an activity is that here people meet and interact to form new meanings that go beyond the evident limits of each of the people involved. The creation of the 'new' is not generated from the old but from the living movement of an activity leading away from the old (Engeström, 1987).

2.3 Situations of dilemma, exploration and the creation of radical solutions

Important in activities are socially essential dilemmas which cannot be resolved through separate individual actions alone. Boundaries, therefore, are experienced as situations when individuals face a dilemma (Kerosuo and Engeström, 2003). This happens in interaction between individuals, and between their ideas. This typically happens in boundary zones between different activities. Creation of new instruments may resolve such dilemmas. This is facilitated through exploratory actions. Then tensions occur, leading to an analytical stage where new abstract models are produced which are tested and reflected upon, and eventually replace earlier ones (Blackler et al, 1999).

Allen (2001) argues that because people have limited knowledge of what lies ahead they therefore cannot know precisely what actions to take at present. It is in the context of this dilemma of ignorance that learning, although never perfect, becomes important. It is in such situations of multiple choices where a diversity of perspectives and ideas are brought together in the supply chain that the exploration into more radical solutions can be made (Rose-Anderssen and Allen, 2008). This exploration into the unknown is achieved by challenging the routines and thinking of the past.

These are characteristics of expansive learning processes. These expansive learning cycles, Engeström (1987) argues, should be viewed as partially destructive rejection of old perspectives and practices. These are important arguments as in several of the companies interviewed, interviewees realised that the industry as such has been conservative. It is therefore a key challenge to move away from the old through the creation of new instruments for change.

As the supply chain is a complex system of multiple work activities, learning can therefore be seen as a self-organisation of collaborative relations and practices. The work activity therefore becomes an ongoing combination of intentions and emergence. Thus as individuals enter an activity, they face the challenge of acquiring the shared artefacts or established cultural means. At the same time they will face situations were they must formulate more desirable cultural means (Engeström, 1999). Due to the dualism between intentional action and emergence where individuals and their activity community are trying to change their situation, they are themselves transformed by these very actions. This is learning in doing. The connection of multiple work activities into a supply chain therefore complexifies learning and change. Supply chain management becomes a complex task of resolving networks of creative tensions that result from multiple dilemmas.

3. Methods of data collection

The research question for the paper is; what are the implications of different levels of learning and transformation of knowledge on competitive advantage? The model created from an activity theoretical point of view defines three levels of learning; adaptive, reactive and expansive. Empirical answers to this were sought through interviews.

Substantial literature research was conducted within several areas of relevance, i.e. on supply chains in general, on aerospace supply chains specifically, on the history of the commercial aircraft industry, and literature on evolution, learning, knowledge and change was conducted. Based on the interpretation of this data, open ended interviews were conducted. The interviewees were presented with a sheet of paper with the following key questions along with issues to expand on: *How have key practices changed and been introduced along the life cycle of an aircraft model and from aircraft model to aircraft model?* This was to be discussed in terms of the issues of: *Types of supplier selection, types of relationships with customers and suppliers; coordination and integration; training, learning and development (that is, how do people learn and therefore change practices?); quality assurance; risks; lean/agile practices; costs; offsets; technology; and future scenarios.* This paper focuses on the transformation of knowledge and learning issues elicited from the interviews.

In these interviews the interviewees were allowed to talk freely and tell their stories. Each interview became a stepping stone of comparison and reflection prior to entering the next interview session. The issues presented were the same each time. But the interviewer's questions on elaboration changed. This constant comparison and reflection on data is typical of the iterative and evolutionary process of discovering grounded theory (Glaser and Strauss, 1967).

The access to industry is always difficult to achieve. This limited the interviews to be conducted at one main airframe manufacturer only. However, the 1st tier suppliers visited for interviews were suppliers to both main competing airframe manufacturers. They could talk about their relationships to both companies. This made them part of a larger supply chain network. Some contacts in this research project were extraordinary helpful. That opened access to other companies. This meant the

interviews could be conducted in Europe, Japan and the USA at the levels of airframe manufacturer and original equipment manufacturers (OEMs)/1st tier suppliers. The interviews were conducted in 7 companies with key senior managers and directors in each company. The interviews were conducted either as individual interviews or as focus group interviews. There were 8 individual interviews, one group of 2 interviewees, one group of 3 interviewees, and one group of 5 interviewees.

Focus group interviews produce an opportunity to observe interaction on a topic talked about. The advantage of individual interviews over focus group interviews is the control the interviewer has with closer communication with the interviewee (Morgan, 1997). Our experience, however, is that our focus group sessions became close conversations between the interviewees. The dialogue between interviewees was only interrupted when the interviewer intervened to ask for elaboration. The interviewees rather collaborated in an activity where the object was to explore and make sense of a specific issue. Due to the interviewees' complementary insights, the synergies produced were arguably an expansion of what the individuals could have produced alone. The atmosphere also became more relaxed than in the individual interviews where the individual may feel under constant pressure to perform.

4. Discussions on knowledge transformation, learning and development

In the following subsection the case is discussed from the point of view of the model of knowledge transformation and learning.

4.1 Inhibited learning and the restrictions of old supply chain routines

Prior to the intervention of Airbus into the world market for large airplanes a rather stable situation of slow evolution of change to practices and products existed. The airframe manufacturing could be argued to be in a context of one dominant voice. The division of labour was therefore based on a hierarchy of decisions with no collective object formation process, as there was one predetermined solution only. The airframe manufacturers produced the instruments, as strictly defined drawings and specifications. Similarly, in the case of military aircraft production a government imposed a strictly defined design on its supplier. In both cases learning, development and change were therefore inhibited. There were no significant disturbances that could initiate irreversible change. The rules of conduct within the companies and between supply chain tiers therefore became resistant to change.

> Traditionally innovation with the suppliers has not been that great. We have done most of it and it is passed down as a detailed spec or a drawing in a sense (Airframe manufacturer).

> [The] aircraft industry in Japan was mainly for military aircraft. Our only customer is the Japan air-defence. [A] military contract is very unique. The only customer is [the] Japanese government, and the only supplier is us. You know, the changing is not that good for military contracts. Changing process experiences is difficult. If we try to change a process of [the] production, Japanese government must approve, inspect and review. They must approve the change process. This is very difficult process. So, historically our production system has not been changed for a long time (Japanese structural supplier).

Knowledge therefore was treated as if it was a commodity that is easily transmitted and controlled. It had served the success of the past. With past success there was apparently no need for a collective object formation process for change. Thus there was no creation of new instruments, learning and change.

4.2 Initial dilemma situation

As the U.S. airframe manufacturers were losing market share to the new European consortium of aircraft manufacturers in the mid 1970s, this triggered off models of strategic international relationships in order to utilise the best supplier expertise there was. The American companies were seeking more integrated systems and therefore looking for more to be done by the individual supplier company. In these new relationships they took into account market access, the suppliers' access to capital and the suppliers' unique technologies. Simultaneously suppliers had to commit themselves to cost reductions to achieve long term relationships with their customer. This was based on formal partnerships and partnership sourcing. It was a more collective channelling of competing interests into shared interests.

> I would say the best learning [we] had was when they [the Europeans] were taking 50% of the market. There is always that when there is no competition you tend to become very arrogant. But as you enter into world competition you start trying to find the best players around the world (Airframe manufacturer).

A situation of creative tension therefore occurred when the US manufacturers lost 50% of the U.S. dominated world market for airplanes. This outsider intervention caused irreversible changes to the whole industry. At first, the responsive reaction from the US airframe manufacturers led to marginal improvements only as they sought out solutions mainly related to cutting costs. Secondly, these environmental disturbances were great enough to create more competitive awareness. This encouraged a practice of seeking out competence among international supplier with unique expertise.

There was therefore a creative tension or dilemma that had multiple and unpredictable paths to possible resolution. The success and speed of the resolution depended on the extent to which the supply chain was able to take advantage of the diversity of experiences and expertise into a collective object formation process, creating new instruments for change.

4.3 Knowledge transfer and adaptive learning

Traditionally airframe manufacturers were in the dominant position of a high technology expert and the supplier would simply manufacture to strictly defined drawings and specifications.

There is a general consensus that the industry is still viewed as very conservative compared to, for example the automotive industry. But with the success of the automotive industry in improving their manufacturing practices and systems, and the increasingly competitive global aerospace industry, major changes were taking place. However, these changes were mainly coming from the top of the chains and emphasise the need for the supply chains to learn from the automotive industry and become lean.

> Coming from automotive, I think there are different ways to do it. This is a pretty conservative industry, generally. The individual is also quite conservative. So the phase change tends to be slower than you would anticipate (Mechanical systems supplier).

Adaptive learning was therefore manifested in the industry's attempt to embrace the lean practices associated with the automotive industry. Although the airframe manufacturer has very successfully implemented lean practices at their production sites, this was not true throughout their supply chains. They have therefore been trying to impose their demands as instruments for change. These demands were acknowledged by a key Japanese supplier. When these demands changed the mind-sets at the top of their company, they became willing to adapt to lean practices. In due course they would impose these practices on their own suppliers. However, their rigid social rules, en-cultured in resistance to changing previously successful practices of the past, had inhibited them from taking the initiative and seeking out lean practices experiences from within their own automotive division. Company behaviour reflected an outlook of closed boundaries which failed to adapt external ideas and create new practices.

> We are facing production problems right now, and they [airframe manufacturer] are, directing us to building under their instructions. So, we are now, you know, learning lean concept. How to do lean activities from them? Now we are learning. The biggest change in this century is the concept of the mind, you know. Our general manager and our executive, now they have changed their minds. We must be lean. So we are trying to change to be lean. The change has happened just recently. It's maybe two years ago, [then]we hadn't thought about that (Japanese structural supplier).

However, in general, the use of e-portals for exchange of information and adapting new practices are shown to be successful instruments for supply chain integration.

> We have developed portals in our system of design and engineering that enables us to work with our suppliers and researchers and partners at a completely virtual basis (Airframe manufacturer).

> We all have portal systems where we export our drawings in, where people can work on them more like real-time. So, it has for the last 10 years, the tools that have enabled the supply chains to become better integrated have improved phenomenally (Equipment supplier).

Still, learning from fellow suppliers about lean production is bringing suppliers up to established industry standards only. Hence, the context is not changing much from the traditional practice of one dominant voice. That is, adaptive learning practices do not bring about enough disturbances for the continual formation of an emergent object. These practices are not boundary crossing and produce marginal improvements only. They are therefore helpful transformations in sustaining in the immediate future only.

By adapting to industry wide practices, it means that every competitor was responding to the challenges of the environment in the same way. They all adapted to

pressure by adopting the marginal improvements of the same industry wide routine behaviour.

4.4 Reactive learning

Reactive learning within a supply chain was identified to take place in three ways. Firstly, the airframe manufacturer argues they have 'lessons learnt' exercises internally to learn from mistakes. Similarly they have random audits to assist suppliers to learn from their mistakes and correct their own work. These are quality improvement issues bringing products and practices up to expected standards only. Secondly, and more dynamically, a supplier is sharing and learning with suppliers to improve products.

> Every quality reject is subject to a regroup cause analysis. And that is a team event were people from the shop floor, from purchasing, people from supplier, people from customer and also support crew, like engineers would be involved (Electrical systems supplier).

Thirdly, good marketing principles were exercised when the airframe manufacturer started to listen to the needs of the airlines. This involvement with the airlines at an early stage of a new aircraft model made a particular aircraft take a huge part of the market compared to the competition. But still only took low risks and had a conservative approach to aircraft development. Compared to previous aircraft they made major improvements to the interior, to the cockpit etc. But these were, however, what they called, integrating point solutions only. They were renewals of some significant parts of old aircraft design rather than launching a totally new type of airplane. The approach therefore gave them marginal competitive abilities only. In practice the changes came about as repairing the single voice of past principles of design.

> A decade ago really, [we] probably felt like it applied more to working together with our airline customers as a stronger connection. In driving the product design the airlines were embodied in the xx [plane], which we have huge part of the market compared to the competition. And I think we have learnt. We have been learning that aspect of collaboration (Airframe manufacturer).

> I think that the xx [plane] was not taking an existing system, but taking low risk and a conservative approach. It is not much different than the other aircraft we have produced. We made improvements with the cockpit, the navigation system and the seating capacity, storage, you know, [the] engine. It is a two engine aircraft. It is very powerful. They were what I call point solutions, moving to an integrated solution. We were very successful with [that plane] (Airframe manufacturer).

These 3 slightly different approaches show good collaborative intentions. But the intentions did not facilitate instruments that are critical to the present, as new and radical perspectives were not brought in. The object remained frozen and they were repairing present tools only and were therefore merely hill-climbing in a smooth and familiar terrain. This made the supply chain competitive but did not bring about innovation and therefore industrial leadership. The example illustrates that whatever

diversity of ideas existed, the inhibitions from embedded practices and old routines were able to stop the creation of critical disturbances for irreversible change to their design and production.

4.5 Major dilemma situation, expansive learning and creating new knowledge

Based on the positive previous experiences with early involvement of airlines, the airframe manufacturer started to spend more time with airline customers to make the passenger experience more rewarding. As part of the early involvement strategy they also started to share more with the 1st tier suppliers at that stage. In that sense the airframe manufacturer was moving from being risk-aversive to accepting risk in order to explore more and become innovative. They became dedicated to continuous development and trained their workforce to improve skills in order to become innovative. This was making them more open to communicating on mutual continuous improvement and sharing more with key suppliers, and they were trying to impose those philosophies down their supply chains.

> We are an extremely risk-aversive company. And I think this is an indication [that] we have started to accept risk and become innovative (Airframe manufacturer).

> We [have] lately spent more time with our airline customers and trying to get to the ultimate customer. Why? In [order] to figure out how to make the whole passenger experience more rewarding (Airframe manufacturer).

> The sustaining programme relationship with the supplier has changed over the years drastically. Today it is much more of an open communication, working together and continuous improvement. We are spending a lot more time educating and training (Airframe manufacturer).

A paradigm shift of philosophy occurred when the airframe manufacturer tried to bring together the best expertise and production capacity with the formalisation of this through risk-sharing partnerships.

> We learn and adapt based on trial and error. But because of that product cycle through our business, we also have to take significant risk to push the development (Airframe manufacturer).

Risk-sharing partners are also chosen for financial and sales reasons. In terms of financial reasons, the suppliers needed capacity to invest in innovation and thus producing a supply chain that has a competitive advantage. With sales, the suppliers are also expected to promote sales in the home countries of potential airline customers. Networks of maintenance and engineering suppliers are also built up in low cost economy countries to support potential sales in these countries. The aircraft manufacturer sees themselves as large scale integrators. Simultaneously they are trying to bring their suppliers up the value chain by trying to also make suppliers more responsible and efficient. The move from being satisfied by exploring within a familiar and optimised terrain into allowing the diversity of a multidimensional performance landscape of risk-sharing partnerships is therefore a bold step into inventing a future for a supply chain.

> We need other companies to be risk-sharing partners. That could be financially. But also from a sales standpoint. Bringing other partners on board to help influence decision makers [in their countries], so that we can increase our sales (Airframe manufacturer).

> We also approached India to develop engineering skills, because we know that when we introduce commercial aircraft into a commercial market these airlines would need engineers [to] help them maintain those airplanes (Airframe manufacturer).

A major dilemma situation occurs due to the contradictions between the tradition of airframe manufacturer exercising customer power over suppliers and the concept of risk-sharing partnerships to enhance product innovation. Such partnerships are based on the dialogical principles of little power difference and closeness between potential partners. However, the airframe manufacturer exercises power as they replace previous contracts with suppliers by risk-sharing partnership contracts. From the moment the contracts have been signed power can be argued to have shifted to the endurable artefact, the contract. The contract from then on becomes an instrument for the development of sharing, creativity and innovation. At the same time, because of its strength, it might inhibit other looser supplier relationships potentially beneficial to the supply chain.

> And if you look at the main contracts for example, for the new airplane, they have called back the terms we have with them. Pretty much straight through. And it is a partnership you know. They have become really a part of our business in the way their contract reflects. There is risk associated with that obviously (Mechanical systems supplier).

This formal action is an attempt to open boundaries and encourage multi-voicedness. At this bifurcation point a path for new behaviour is initiated. Thus several dilemma situations occur. These are shifts of roles from being suppliers and being told what to do, to becoming risk-sharing partners exercising expert power and having a voice and becoming responsible. These are moves from the marginal innovative potential based on previous experience and financial ability to actually stretch boundaries by implementing innovative solutions.

> Before it was; ‘here is your contract, this is what you do’ (Airframe manufacturer).

> So as opposed to previously, we would have supplied subsystems and components. But [now] our responsibility is to integrate that and give it to the airframe manufacturer. It is that integration the airframe manufacturer previously have done themselves (Mechanical systems supplier).

Finally, the outcome of the risk-sharing partnerships has so far shown unique innovative strength in terms of a conceptually new product. By bringing together the best expertise and financial strength available it has therefore facilitated dialogue followed by expansive learning and innovation beyond expectation. Still the partners are on the move of good intentions to continually improve the implementation in

praxis. They are still learning through adaptation, reaction and exploration at all levels of the supply chain.

> And some of the things that I [have] read, that has truly made me proud about us in the last six months is, throughout the world, our new airplane is recognised as an extraordinary high technology advanced aircraft. People believed that we have stepped out a very innovative solution. We have stretched the boundaries of technology, offered a unique solution that has never been offered to the industry before. And we have always felt that internally. The industry is concerned because of the innovation. We are an extremely risk aversive company. And I think this is an indication we have started to accept risk and be innovative. Quite honestly we have to be global. We have to have those relationships. So globally is, I think those supplier relationships are really important. If we want to be a large system integrator then we have to trust other people. And the only way we can trust other people is [in] relationships. It can not just be a business relationship it has to be a risk sharing relationship (Airframe manufacturer).

The financial power and expertise of every partner made it possible to collectively explore, learn and develop the new aircraft concept. The risk-sharing partnership facilitated the collective object formation process through exploring, learning and creating the new.

5. Conclusions: Knowledge transformation and levels of learning

In this paper, the intervention started off when the airframe manufacturer tried to make sense of the more rapidly changing global market. This posed a major dilemma, and the airframe manufacturer realised that it could not be resolved either technologically or financially, by them alone. The new instrument chosen for resolving their dilemma was therefore risk-sharing partnerships. Once this had been decided it represented a major bifurcation point in the evolution of their supply chains. Thereby the old system of vertical domination became obsolete and a collective movement of partners was chosen to explore new opportunities. And the exploration of new opportunities was based on the inherent expertise accumulated by each partner. The challenge was however, how to develop this further. The new instrument of risk-sharing partnerships facilitated a new division of labour by sharing of diverse expertise for exploring new solutions.

These ideas of adaptive, reactive and expansive learning correspond to ideas used in earlier work by Allen et al (2006) on “cladistic” evolution of organizational forms. In describing organisations as being bundles of practices, skills or techniques, the evolution of the industry was seen as an evolutionary tree created by the successive adoption of new practices. However, for many organisational forms the new practice might well come from other organisations in the industry and would correspond to “adaptive” or “reactive” learning. However, sometimes a new practice would emerge from within a particular organisation and then it would correspond to “expansive” learning. In the cladistic papers, however, there is no distinction made between practices that are coming from elsewhere and those that emerge from within. Al that matters is whether or not the new practice is adopted or not. In some ways the detailed reflection here resulting from the interviews in the aerospace sector throw more light on the processes that lead organisations to create a new practice, which may diffuse across the industry.

It is essential to appreciate that all three forms of learning act together. As individuals or groups interact in a common activity they adapt successful practices from each other. They react to external changes and their own mistakes. They co-develop new practices. The collective learning therefore can be argued to be fluctuating between the three forms of learning as the context of the activity changes. The context changes due to imperfect and varied human interaction. The simultaneously occurring collective learning that is developing new meanings enhances the collaborations skills for implementing new practices.

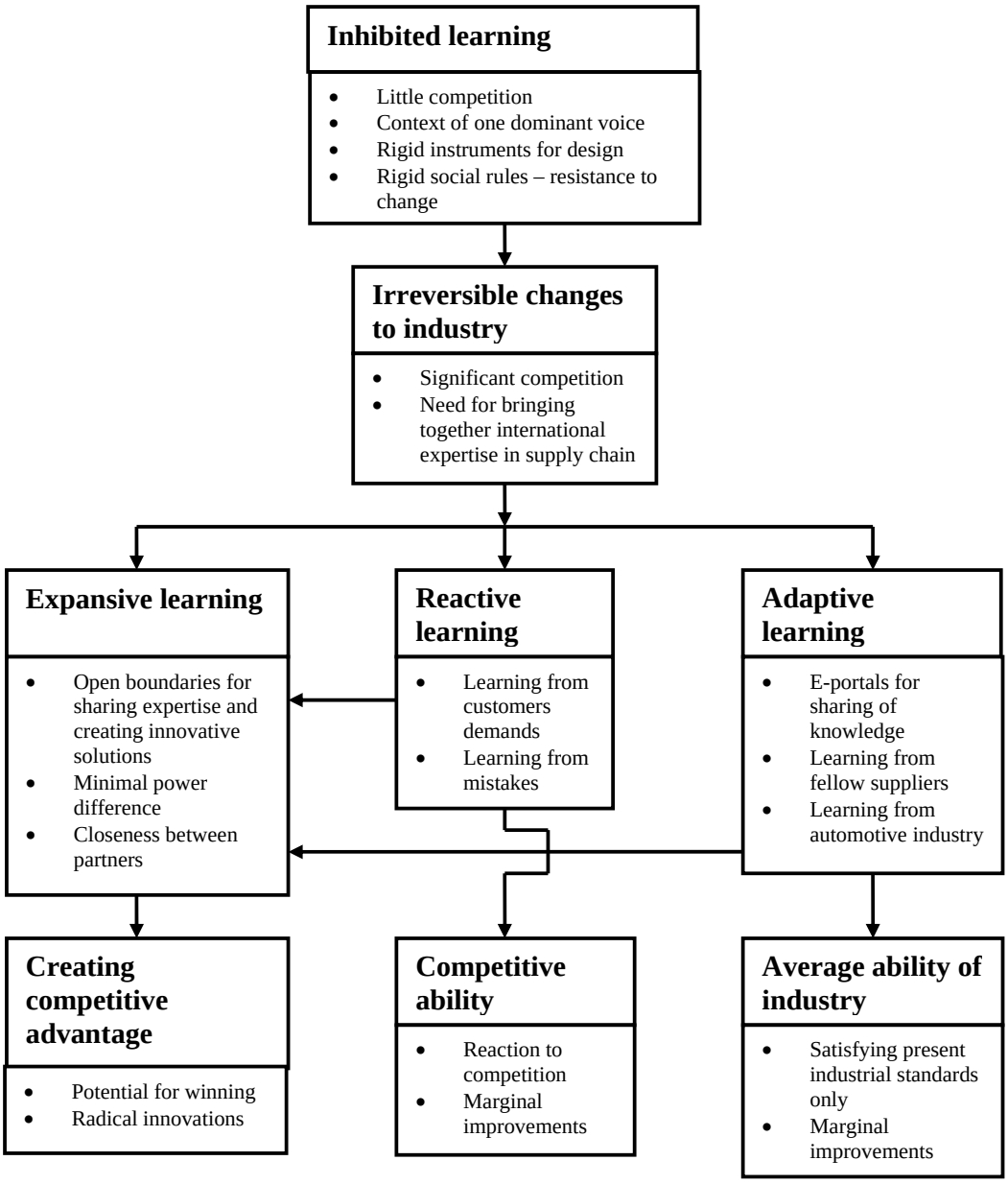

Figure 4 Implications of levels of learning for aerospace supply chains

A simple rule is that adaptive learning in supply chains is about getting practices up to the present quality standards of the industry or comparable industries. Reactive learning is about getting practices that makes the supply chain able to compete. And expansive learning is about getting practices that gives the supply chain a potential for winning. In the long run, however, they need to act together.

Due to successful learning and development with one airframe model and its supply chain, the respective practices and systems are transferred as routines for other airframe supply chains. These then become established as new supply chain forms. In that sense the airframe manufacturer's success becomes the strategies for change for entire supply chains. This illustrates a clear path dependency of practices due to successful previous implementations.

> It is much easier for us to take new technology, [and] get it on a new airplane model than to retrofit new technology back on an existing model. …. We are starting to have a better understanding of technology capability. I think we're on getting them on the next airplane programme. We are learning that from the [new aircraft] and the learning that comes out [from that experience] (Airframe manufacturer).

However, the success of new supply chain forms in the long run become resistant to change until their inner contradictions exceeds stability and people engage themselves in the similar reflective processes that created them. The facilitation of continuous practices of collective reflection therefore is likely to become the essential instrument for innovative solutions and sustainability of a supply chain and its member firms.

The model of knowledge transformation through adaptive, reactive, and expansive learning could be useful in research when focusing specifically on changes to an existing supply chain. In terms of more interactive research with industrial partners the model could be applied to a supply chain in the process of being established. An understanding of the implications of the differences between the three concepts of learning could assist the management involved in the processes of supply chain change. Subsequently they could apply the learning mechanisms most appropriate at the different stages of change.

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